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Granular Trenches and Stone Columns as Ground Improvement Techniques-Case Histories of Field Applications

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SYNOPSIS Vast areas of Deposits of Soft clays and loose sands is a common occurance generally in all the countries particularly in the Coastal towns of the State of Andhra Pradesh, India. The utility of these deposits for founding structures becomes vital inview of the enaromous land cost and their existence in developed areas. The structures resting on these deposits will be subjected to many problems as these deposits possess very low insitu strength. Appropriate ground improvement technique, supported by quality assurance tests after implementation of technique in the field will be a better solution in problematic soils. The paper aims in presenting the field applications of Granular Trenches and Stone Columns for the construction of Bus Stations at three different regions.

INTRODUCTION

The problems related to the assessment of bearing capacity and the choice of the appropriate foundation are generally more in very weak soils. There are many field situations where atleast a moderate increase in the bearing capacity of the weak soils is desired for the satisfactory construction of suitable foundations. One such solution for improving the bearing capacity of weak soils is by installing granular piles or stone columns. The plane strain version of a granular pile is a granular trench. A controlled and careful application of granular trenches can yield satisfactory results.

There are many ground improvement techniques to improve the strength and compressibility behaviour of these deposits. Important among these techniques are stone columns, lime columns, granular trenches etc. The choice of a particular technique depends upon the soil profile at a site, quality of materials used in the technique, nature of pore fluid and the method of implementing the technique. Further the successful application of a ground improvement technique depends also on the quality assurance tests conducted for the improved behaviour of the ground and the performance studies spread over certain period by maintaining settlement records etc. Even though substantial work through research has been carried out on these techniques, confidence to any field Engineer develops mainly based on the successful field applications.

BRIEF REVIEW OF LITERATURE

One of the many techniques in use for improving the load bearing capacity of shallow foundations in soft or weak soils is the use of stone columns as reported by Hughes and Withers (1974) and Hughes et al. (1975). Similar to the stone column technique, granular trenches in weak soilswhich can be considered as a plane strain variation of the stone column approach, can also be used to support strip foundations. The use and analysis of stone columns are treated in published studies by several authors such as Mitchell and Huber (1983,1985) and Barkadale and Bachus (1983). Analytical investigations were presented modifying the Rankine theory to take into consideration the bulging of granular trench or adopting general shear failure pattern, similar to the one adopted in Terzaghi's equation. Madhav and Vitkar (1978) proposed a Theoretical solution for the ultimate bearing capacity of shallow strip foundation supported by a granular trench. A number of laboratory model tests on granular trenches were conducted by Hamed et al. (1986) to vertify the various theories and theoritical solutions.

It was concluded that the ultimate bearing capacity of the foundation increases with increase in depth of the granular trench attaining a constant value at some depth of trench. The conclusions were based on small scale laboratory tests and preferring width of trench less than the width of footing. However it may not be possible to excavate a vertical trench in soft clay for a size less than the size of foundation. In practice it is convenient and desirable to have granular trench width more than that of the foundation.

APPLICATION OF GRANULAR TRENCHES FOR BUS STATION SITE AT BHIMAVARAM AND NAGAYALANKA (Coastal Towns in Andhra Pradesh, India)

Site at Bhimavaram Town

The Andhra Pradesh State Road Transport Corporation (A.P.S.R.T.C) have proposed a permanent Bus Station Complex on a site which was originally a tank bed. The soil profile at the site consists of 4m of filled up soil as top layer followed by fine sand of 3 to 4.5m thickness. This layer is followed by clayey soil upto depths of 30m below the ground level. The soil profile at site is shown in Fig.1. The technique of granular trenches has been adopted to this site. A granular trench of 1.5m to 2.0m thickness has been provided on the top of fine sand so that the strip foundations laid on the granular trench transfers the loads on to the fine sand layer. After excavation of the top 4m of filled up soil, back filling with well graded sand in layers of 20cm has been done vibrating every layer so as to get a relative density of 70 to 80%. The granular trench has been taken to cover a further width of 1.5 times the size of footing on either side of the strip foundation as shown in Fig.2. After bringing the level of the granular trench to the proposed depth of foundation a plate load test has been conducted on the surface of the granular trench with reaction loading to ascertain the load carrying capacity. The load settlement curve obtained is shown in Fig.3. It can be seen from the Fig.3 that noticeable increase in bearing capacity has been obtained by adopting granular trenches. The safe bearing capacity computed based on Terzaghi's formula is quite satisfactory when the width of trench is sufficiently more than that of the foundation. As the clay layer below the of fine sand has a low strength, the intensity of stress transferred on clay layer through the granular medium by dispersion has been worked out and verified that intensity is smaller than the strength of the clay layer.

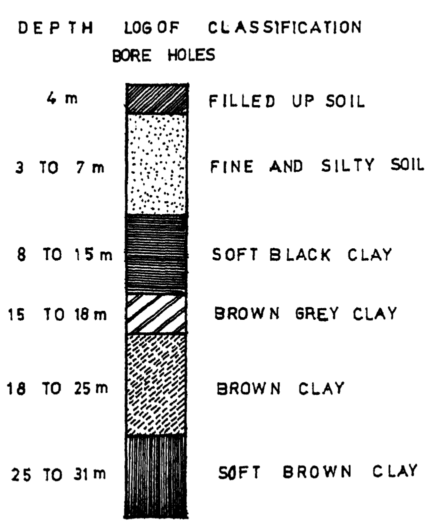

Fig.1 : Soil Profile (Bhimavaram Site)

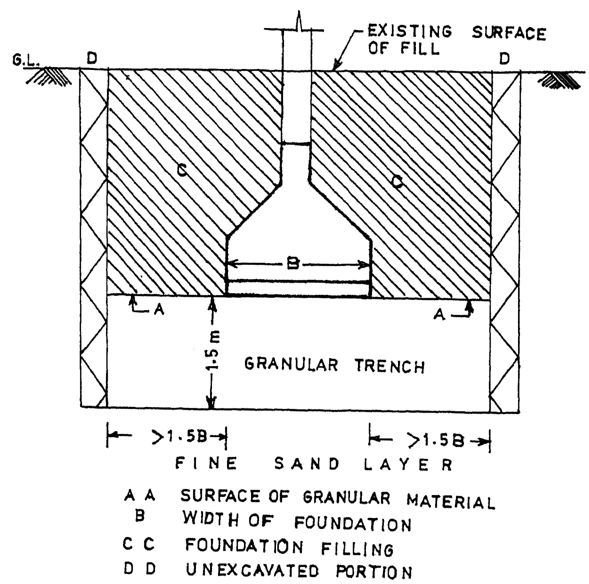

Fig.2 : Footing on Granular Material

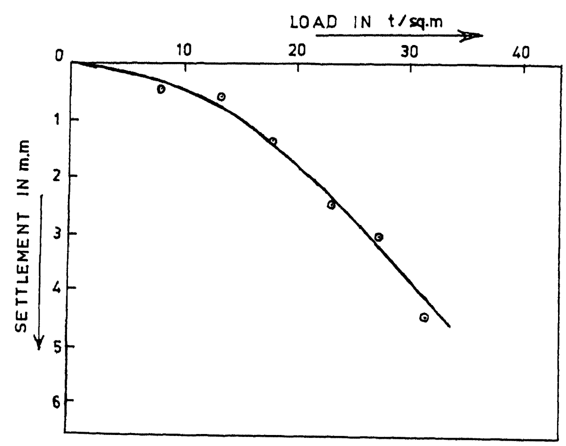

Fig.3 : Load-Settlement curve from plate load test on Granular Trech (Bhimavaram Site)

Site at Nagayalanka Town

At this place also the A.P.S.R.T.C had proposals for construction of a Bus Station on a site which was a tank with standing water of 3m depth in tank. The soil profile at the site below bed of tank consists of clayey soil of 1.1m thickness as top layer. Below this layer silty sand layer exists and continues to considerable depths. The soil profile is shown in Fig.4. For this site also the technique of granular trench has been adopted. The width of granular trench below the foundation is taken to a width on either side of footing by 1.5 times of width of footing as shown in Fig.2. The complete thickness of top clayey soil has been removed and the area meant for construction is backfilled with locally available sand in layers of 30cm and each layer is compacted by vibration using sufficient water so as to get a relative density of 70 to 80%. This has been ensured by introducing density bins during compaction of each layer and the density so obtained has given 70 to 80% relative density uniformly. The top of granular trench so made over the area of construction is kept at 1.5m depth below the surrounding ground level.

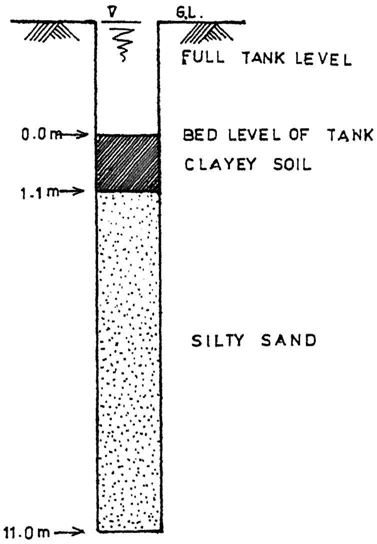

Fig.4 : Soil Profile (Nagayalanka Site)

A plate load test on the top of the granular trench is then conducted using reaction loading to assess the load carrying capacity of the granular medium. The load-settlement curve obtained from the test is shown in Fig.5.

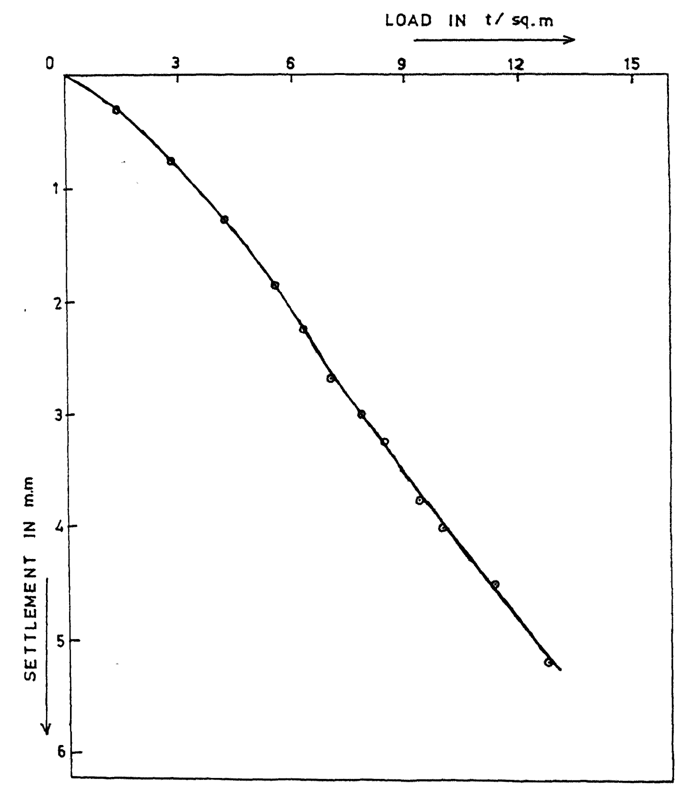

Fig.5 : Load Settlement Curve (Nagayalanka Site)

The settlement of the plate corresponding to $8t/m^2$(the safe bearing capacity adopted in the design of foundation) is noted from the graph and making use of this, corresponding settlement of the foundation has been computed and it came to 5mm which is a safe value keeping in view the permissible angular distortion of the frame as 1/500 when l is spacing between columns (l=5m). The existence of sand layer at some level helped to adopt granular trench by utilising the naturally available sand or fine sand layer for transfer of load intensity such that the subsoils of low strength are not over stressed.

STONE COLUMN AND GRANULAR TRENCH TECHNIQUE AT KAIKALUR (A town in Andhra Pradesh State in India)

About the Site

The Andhra Pradesh State Road Transport Corporation acquired a site in the heart of the town Kaikalur but is also a tank of rearly 2 acres in area with depth of water in tank as 3m. The soil is almost adjoining a canal. Boring operations cnducted over this site revealed a silty sandy soil with clay binder of 1.5m thickness from the bed level of the tank as top layer. This layer is followed by soft clay to considerable depths. The soil profile is shown in Fig.6.

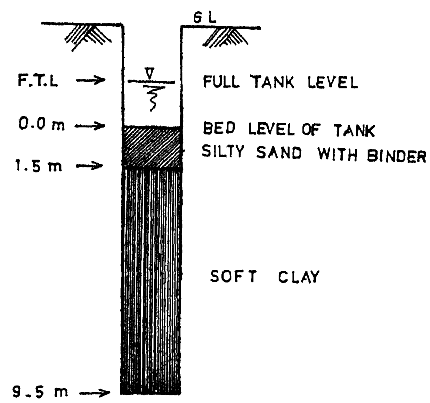

Fig.6 : Soil Profile (Kaikalur Site)

Adoption of the Technique

After bailing out the water completely in the tank, the top 0.5m thick soft soil is removd over the entire area proposed for construction and the bed is allowed to dry partially. Stone columns have been formed at a spacing of 1.0m and of 225mm in diameter. For this purpose bores have been made to 3.0m depth below bed level of tank. The bottom 2.0m depth has been filled with graded metal of 40mm to 25mm mixed with sand. The filling is done in layers of 30cm thickness well compacted with a standard rammer. After the stone columns are thus formed over 2.0m height the top 1.0m in all the bores has been filled with sand and well compacted to bring this 1.0m of sand inline with fine sand layer in between stone columns. The total area covered by stone columns is 25m X 40m.

From this level (the bed level of tank) well graded granular material (sand) has been introduced in layers of 30cm thickness, over an area larger than entire area of construction. Each layer is compacted by vibration adding sufficient quantity of water so as to obtain a relative density of 75 to 80%. The granular layer is thus made to a thickness of 1.5m above the bed level of the tank. The top of this granular layer is considered as the level for laying the footings.

Plate Load Tests

In order to assess the improvement in the strength of subsoil as a result of installation of stone columns a plate load test has been conducted at bed level of tank at a selected position and at the centre of the grid formed by stone columns. The load-settlement curve obtained from the test is shown in Fig.7. Failure has been noticed when the applied load intensity is $5t/m^2$ due to excessive settlements. This fact confirms that the strength of the sub soil has increased to some satisfactory level due to the installation of stone columns. It may be noted that the strength of sub soil before the stone columns are installed is almost negligible. It can be inferred that the permissible intensity that can be allowed at this level (bed level of tank) due to footing at higher level can be at best 1.5 to $2.0t/m^2$.

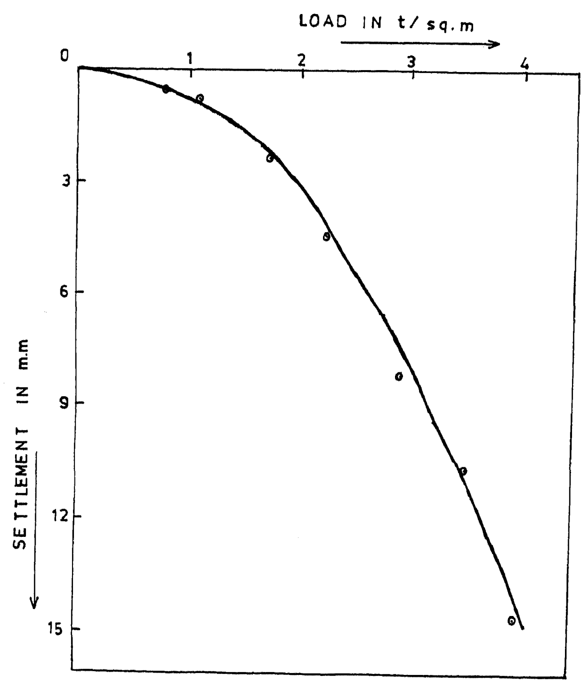

Fig.7 : Load Settlement Cuve at Bed Level (Kaikalur Site)

Two more plate load tests have been conducted at selected positions on the top of the compacted granular (sand) medium to assess the strength behaviour as the footings are to be laid at this level. The load-settlement curves obtained from the tests are shown in Fig.8&9. It can be seen from the results furnished in Fig.8&9 that higher values of safe bearing capacity can be concluded at this level of top of granular medium. Even though higher values of safe bearing capacity can be allowed at the footing level the permissible bearing capacity has been limited to $4t/m^2$ only due to the reason that if higher values are adopted they cause excessive settlements in the sub soil below bed level. It is equally necessary to see that the intensity transferred at bed level is not more than 1.5 to $2.0t/m^2$. Taking this in to consideration a safe bearing capacity of $4t/m^2$ is concluded for the design of footings at the footing level so that the intensity transferred to the bed level is of the order of 1.5 to $2.0t/m^2$. For this intensity the likely settlement of the structure can be well within the limits.

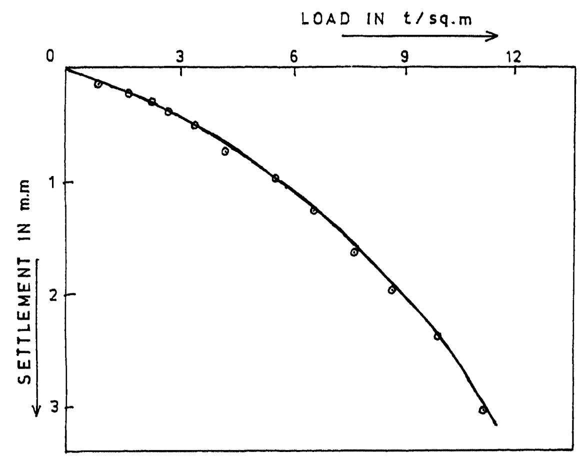

Fig.8 : Load Settlement Curve at Foundation Level (Kaikalur Site)

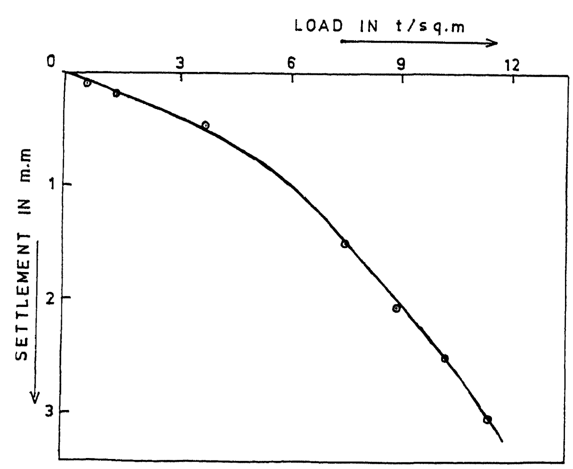

Fig.9 : Load Settlement Curve at Foundation Level (Kaikalur Site)

At all the three locations, bus stations have been constructed and commissioned. Settlement gauges have been installed at important column locations to maintain record of settlements. Records have already been made over the last three years and the settlements attained so far are of the order of 5mm to 8mm with no marked increase later on.

CONCLUSIONS

The adopted Ground Improvement Techniques in all the three different sites have helped to improve the performance of sub soils and the bearing capacity considerably.

As a result of the adoption of these Ground Improvement Techniques at the sites, it was possible to make these sites suitable for the construction of Bus Station. Conventional foundations are unsuitable as the subsoils have low to very low strength basically.

The adoption of the Ground Improvement Techniques as field applications have helped in a large way in creating confidence in field Engineers.

Even though substantial work through research has been carried out on Ground Improvement Techniques, Confidence to any field Engineer develops mainly based on the successful field applications. The three sites selected have given scope for identifying the application of granular trenches and stone columns as appropriate Ground Improvement Techniques.

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